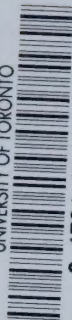


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PERIODONTAL STUDIES

Nos. 1, 2 and 3

by

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STUDY NO. 1

THE ORAL CAVITY



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THE ORAL CAVITY

A. The Oral Cavity

The oral cavity in the human is comprised of two main parts, an outer section called the vestibule and an inner division known as the oral cavity proper. When the teeth are normally present and in contact in centric occlusion, the crowns together with the roots and their supporting structures constitute a partition which separates the vestibule from the oral cavity proper. The oral cavity, strictly speaking, is not a true cavity when the mouth is closed at rest. Then, the tongue comes in contact with the walls of the oral cavity proper on all sides with the exception of the posterior part where an open space occurs. The vestibule also does not exist normally as a space, as the mucous membrane of the lips and cheeks rests upon the crowns of the teeth, the gingivae and the alveolar mucosa.

Into the oral cavity, numerous glands pour their secretions, some into the vestibule and others into the oral cavity proper. These are known as the salivary glands, and their secretions are called saliva. The smaller glands appear to function continually and thus keep the oral mucous membrane moistened and lubricated. In the larger glands, the salivary glands proper, in normal life, secretion is brought about reflexly in response to various stimuli. Certain stimuli exert their influence upon the peripheral endings of the sensory nerves of the mouth to produce secretion (the unconditioned or inherent reflex). Others act, not on the nerves of the mouth but on one or other of the organs of special sense e.g. sight and smell (the conditioned or acquired reflex).

I. The Oral Vestibule

(1) Boundaries

When the lips are closed, they form, with the cheeks, the outer wall of the vestibule. The surface of the inner wall comprises the labial and buccal surfaces of the crowns of the teeth, the gingivae and alveolar mucosa when the teeth are in centric occlusion. The general configuration is therefore determined by the dental arches. The two walls are in contact when the vestibule is not distended. Preiswerk¹ has pointed out the peculiarity that in mastication, the cheeks do not collapse between the molar teeth. This is accounted for by the presence of a firm membrane intertwined with the buccinator muscle which produces folds in the mucous membrane. In this way, it is prevented from penetrating between the occlusal surfaces of the teeth as they come together.

(2) Associated Salivary Glands

According to Maximow and Bloom;² "all glands of the oral cavity independent of their size belong to the compound type", that is to say they consist of "several or many units or systems which are called lobules". The glands which open into the vestibule are the two parotids

and the numerous small labial and buccal glands. The labial glands are situated in the mucous membrane of the upper and lower lips, and the buccal glands are a continuation of them in the mucous membrane of the cheeks. Certain writers refer to molar glands, larger than the buccal, with ducts opening near the third molar teeth.

The ducts of the parotid glands, known as the ducts of Stenson, open into the vestibule on the buccal surface of the cheeks opposite the upper right and left second molar teeth. Here, a small papilla marks the outlet of each duct. This orifice is the narrowest part of the duct and just permits the entrance of a small probe. Each duct is about two and a half inches in length and commences at the anterior portion of the parotid gland. Passing over the masseter muscle to its anterior border, it curves inward almost at a right angle. It then pierces the cushion of fat and the buccinator muscle, and continues obliquely forward beneath the mucous membrane to its opening

(3) Salivas

The parotid is the largest of the salivary glands, and lying in front of and below the ear, it occupies the ramus of the lower jaw. It is a pure serous or albuminous gland, that is to say the terminal or secretory portions of the glandular cavities contain only serous cells.

The secretion is thin and watery as a rule, though occasionally it may be turbid. It lacks mucin but contains salts, proteins and ptyalin or salivary amylase. It varies little in the relative amounts of its inorganic and organic constituents with the two classes of stimuli, viz. food and irritants, thus differing from the secretion of the submaxillary gland.

Parotid saliva on account of its watery character is well adapted to the functions of cleansing the mouth and teeth, moistening and softening dry food, and dissolving many substances in order that they may stimulate the taste buds of the tongue. Through its ptyalin content, under favourable conditions, starch is converted, for the most part, into maltose. It is unlikely that this action occurs to any appreciable degree in the food bolus before it is swallowed but it is highly probable that under certain circumstances, considerable digestion of starch takes place in the stomach.

The labial and buccal glands belong to the mixed type, that is to say both mucous and serous cells are present in the terminal portions of the glandular cavities. In consequence, their secretion moistens the mucous membrane, and also lubricates it through its mucin content which tends to be mucilaginous and ropy.

(4) Reaction of parotid saliva

References to the reaction of fresh human saliva from the various salivary glands proper are not common in the literature. Such saliva usually has been obtained by inserting a fine cannula into the opening of the ducts. Observations have been made on human saliva collected from cases where, as a result of accidental injury, a fistula has been

established. Normal salivary secretion in animals is sometimes studied by the creation of a fistula, the duct being diverted to the outside of the chin or cheek. The saliva is then easily collected and analysed.

According to Schafer,³ Raymond,⁴ Hammersten and Hedin,⁵ and Brubaker,⁶ human parotid saliva is alkaline in reaction. Schafer, and Hammersten and Hedin have stated that the first few drops secreted may be acid, and that the alkalinity of parotid saliva is less than that of the saliva from the submaxillary gland. This latter opinion has also been expressed by Raymond.

The findings of the writer in the reaction of parotid saliva under the conditions described previously are in marked disagreement with those of Schafer, Raymond, Hammersten and Hedin, and Brubaker. In 200 different parotid salivas tested, 178, or 89%, showed an acid reaction; 14, or 7%, were alkaline; and 8, or 4%, neutral.

II. The Oral Cavity Proper

(1) Boundaries

When the teeth are closed in centric occlusion, the oral cavity proper is bounded anteriorly by the lingual surfaces of the crowns of the incisor and cuspid teeth, and laterally by the lingual surfaces of the crowns of the bicuspid and molar teeth, together with the associated gingivae and mucosa of the alveolar process. The roof is formed by the palate, the anterior part with its osseous base being known as the hard palate. The posterior or muscular portion is called the soft palate. The true floor is formed by the mylo-hyoid muscle and the base of the tongue. Posteriorly, the oral cavity proper extends to the so-called isthmus of the fauces.

(2) Associated salivary glands.

According to Maximow and Bloom, the glands of the oral cavity proper are as follows:

i. Glossomandibular glands opening on the bottom of the oral cavity between the tongue and the mandible.

1. Mandibular (submaxillary) gland--a large gland with a duct opening at the side of the frenulum of the tongue.
2. Sublingual glands, situated beneath the mucous membrane at the side of the frenulum of the tongue. Among them:
 - (a) The large sublingual gland with a duct opening into the duct of the mandibular gland.
 - (b) Several small glands varying in number and size. Their ducts open in many places along a fold of the mucous membrane, the plica sublingualis. At the posterior end of this group are the small glossopalatine glands.

ii. Glands of the tongue, lingual glands:

1. Anterior lingual glands (gland of Blandin or Nuhn) situated at the side of the median line under the apex of the tongue.
2. Posterior lingual glands:
 - (a) Albuminous or gustatory glands, glands of v. Ebner connected with the circumvallate papillae and opening into the circumvallate groove.

- (b) Mucous glands of the root of the tongue.
 iii. Glands of the palate, palatine glands."

Each submaxillary duct, or duct of Wharton, opens into the mouth through a soft eminence or papilla, the salivary caruncle, at the back end and side of the frenulum of the tongue. Each duct of the large sublingual gland, or duct of Bartholin, usually enters the mouth through the same orifice. Some authorities state that this duct occasionally opens upon the mucous membrane near the orifice of Wharton's duct. The small sublingual ducts, or ducts of Rivinus, are eight to twenty in number and open separately upon the surface of the mucous membrane over the ridge formed by these glands, the plica sublingualis.

(3) Salivas

The submaxillary gland of man is a serous and mixed gland, that is to say the majority of the terminal portions of the glandular cavities contain only serous cells, while the others are mucous with serous cells in the blind ends. The secretion is usually described as a clear, rather thin and somewhat viscid liquid which tends to froth easily. It contains mucin, salts and ptyalin. It should be pointed out, that depending upon the nature of the secretory stimulus, submaxillary saliva may be either thin and watery, through sparsity of mucin, or thick and viscid when rich in mucin. Foods in general stimulate a secretion rich in mucin while irritants produce a profuse flow of watery saliva.

The sublingual glands are mixed glands with the mucous cells much greater in number than the serous cells. The serous cells have a marked muco-albuminous character. The secretion is ordinarily clear and mucilaginous and contains mucin, ptyalin and salts.

The mucin in submaxillary and sublingual saliva serves to lubricate the food preparatory to swallowing.

The glosso-palatine glands, the glands of the root of the tongue, and the palatine glands are all pure mucous glands. The posterior lingual glands connected with the circumvallate papillae as a rule contain only serous cells, while the anterior lingual glands contain mucous and muco-albuminous cells in the posterior portions, and muco-albuminous cells only in the anterior parts.

(4) Reaction of submaxillary and sublingual salivas

As was pointed out previously, the duct of Bartholin from the large sublingual gland usually enters Wharton's duct from the submaxillary gland and the mixed secretions of these glands then flow through a common orifice in the salivary caruncle. It is obvious therefore that pure submaxillary saliva is rarely if ever encountered in these tests. For tabulation purposes, however, the secretion flowing through the salivary caruncles is classed as submaxillary saliva, as undoubtedly it forms by far the larger proportion.

Schafer, Hammersten and Hedin, and Brubaker have stated that these salivas have an alkaline reaction, and are in general agreement

that the sublingual saliva is more alkaline than the submaxillary secretion.

In the 200 submaxillary salivas tested by the writer, 89, or 44.5%, showed an alkaline reaction; 74, or 37%, were acid; and 37, or 18.5%, neutral. In the 200 sublingual salivas tested, 87, or 43.5%, showed an acid reaction; 82, or 41%, were alkaline; and 31, or 15.5%, neutral.

It will be of interest to observe the grouping of reactions of the different salivas in the 100 individual patients examined. Three main groups will first be considered, viz. (a) in which all the salivas, that is to say the secretions from the two parotid, two submaxillary, and sublingual glands, showed an acid reaction; (b) in which all the salivas were alkaline; and (c) representing the mixed types. The all acid group was 34%; the all alkaline group only 4%, and the group representing the mixed types, 62%.

B. The Technique of Approximate pH Determinations of Salivas

(a) Indicator employed

In this study of the reaction of salivas of patients seen in periodontal practice, the writer made a series of approximate pH determinations in 100 different individuals, in each case using fresh saliva from the mouths of the ducts of the different salivary glands proper. The indicator known as Nitrazine and recently introduced by Squibb was employed. This new indicator is available both as a 0.1 per cent solution in dilute alcohol and in treated paper strips. The paper form was chosen because its wide range of color gradations, and corresponding pH determinations (pH 4.5 to pH 7.5) are particularly applicable to the study of salivary reactions. Acid, alkaline or neutral reaction of saliva can readily be ascertained. Further, this indicator allows the determination of pH of solutions within fairly narrow limits, viz. two-tenths to three-tenths of one pH unit.

(b) Parotid salivary tests

Nitrazine paper is available in strips 50mm. long and 7mm. wide. For the salivary tests, each strip was cut into small triangular pieces which are specially suitable for placing over the duct openings, on free surfaces like the soft palate and in gingival crevices and pockets. They are also particularly valuable under conditions where the amount of obtainable fluid is small. In the cases of determination of the reaction of parotid saliva, the cheek was first gently held away from the teeth, and the mouth of Stenson's duct and the mucous membrane for an inch or so around it carefully dried with cotton. Then, with the pliers, a small triangle of Nitrazine paper was placed over the mouth of the duct. When the paper had absorbed a sufficient quantity of saliva to saturate it throughout, it was immediately removed and placed on a white background, preferably glass, and examined for color value at the end of 60 seconds. This procedure is easily and rapidly carried out, and ensures against the loss of CO₂ in the saliva. A loss of CO₂ causes a rise in pH, and in certain methods of salivary collection and examination, it is a disturbing factor.

(c) Submaxillary and sublingual salivary tests

The pH determinations of submaxillary and sublingual salivas were carried out immediately following the parotid tests. A cotton roll was placed over the mouth of each Stenson's duct, and the floor of the mouth gently dried with cotton, with the tongue raised. Four triangles of Nitrazine paper were quickly placed in position with the pliers, one on each salivary caruncle, and one about half way back on each plica sublingualis. When each triangle of paper was saturated throughout, it was removed to the white glass background and examined for color value at the end of 60 seconds.

(d) Conditions under which the tests were made

All the pH determinations in saliva were made on patients as they were presented in the ordinary routine of periodontal practice. And in all cases, the tests were carried out prior to all procedures of oral examination or treatment. Also, no preliminary mouth washing was permitted. It was impossible, of course, to eliminate such stimuli of the organs of special sense other than that of taste, in particular sight and smell, which are associated with the average dental office.

(e) Resting and activated saliva

Saliva may be "resting" or "activated". According to Brawley, "the term 'resting saliva' is given to saliva without any form of induced stimulation." "Activated saliva" is saliva secreted by induced stimulation, and is commonly understood to be more alkaline than "resting saliva". Marked activation of parotid saliva has been noted by the writer almost immediately following certain operative procedures. The problem arises as to the possible activation of parotid saliva as a result of the manipulation involved in the making of pH determinations as previously described. It seems reasonable that any stimulation produced thereby should be more pronounced in the right parotid saliva, in contrast to the left, as this saliva was always tested second in the order of pH determinations. More time is thus permitted for the induction of salivary flow from the right parotid gland from the first manipulation, and a second manipulation is involved as well. The results show that the average pH of the right parotid saliva is only .03 higher than the left. It would appear, therefore, that in these tests, the saliva dealt with is, in general, a "resting saliva".

C. The Problem of Reaction of Human Mixed Saliva

Mixed saliva is usually obtained by having the patient allow the saliva to collect naturally in the mouth and then expectorate it into a dish or tube; or by depressing the head, everting the lower lip, and allowing the saliva to drip into a container. In the obtaining of "resting saliva", no chewing or undue movements of the jaw are allowed for 30 minutes prior to the saliva collection.

While the majority of older text-books refer to mixed saliva as alkaline in reaction, a change is to be noted in the more recent works where it is stated to be neutral or slightly acid in reaction. The

results of many recent investigations, notably those of Brawley,⁷ Starr,⁸ Bunzell⁹ and Cassarato¹⁰ have indicated that the average pH of normal resting saliva lies on the acid side of neutrality. Brawley found the average pH of normal resting saliva for 3405 cases to be 6.75.

Mixed saliva is usually understood to mean the saliva as found in the mouth, the product of all the salivary glands. In other words there is assumed to be a saliva common to the oral cavity as a whole which represents the mixed saliva collected in the test-tube and commonly used for testing and analysis. It is recognized that the salivary environment of the crowns of the teeth is one of the most important factors affecting their integrity. That the crowns of all the teeth, apart from the mastication of food, chewing of gum and like conditions, are commonly found in an environment of thoroughly mixed saliva of all the glands seems highly improbable.

When the parotid saliva is acid in reaction at the duct openings, and the submaxillary saliva is correspondingly alkaline, an acid reaction usually prevails in the oral vestibule, with the exception of the lower labial region. Here, the influence of the submaxillary saliva is usually manifested with the production of neutral or alkaline reactions. The degree of the acid reaction in any other vestibular region may bear a relation to the proximity of the duct opening, but this is by no means a constant finding. Cases have been observed in which the degree of reaction in the upper labial region was the same as at the mouth of Stenson's duct, and others again, in the same region, showed a less acid reaction. Whether this is due to loss of CO₂, or mixing with alkaline secretions of the labial or buccal glands or saliva from the oral cavity proper, the writer is unable to state. Other cases have been noted in which the saliva in the upper labial region showed a more acid reaction than at the parotid duct opening. It is possible that here, acid secretions from the labial or buccal glands have played a part.

The reaction of the saliva in the oral cavity proper is dominated, in certain regions, particularly along the sides of and under the tongue, by the secretions from the submaxillary and sublingual glands. When the teeth are normally present, it is improbable that any considerable mixing with the parotid salivas takes place in the resting state. Evidence of mixing of the salivas of the oral vestibule and the oral cavity proper, as indicated by reaction, is to be found on the surface of the tongue and soft palate. Numerous pH determinations of saliva on the upper anterior surface of the tongue were made and compared to those of the soft palate in the same cases. When related to the average pH of the six salivas tested, as some evidence of mixture, it was discovered that the pH of the saliva on the soft palate coincided with the average twice as often as the pH of the tongue. The tongue reactions were also more alkaline than this average in a much greater number. The soft palate reactions, however, were more acid in a greater number. The pH of the saliva on the soft palate also lay between the pH limits of the six salivas in each case, in a great many more instances than the tongue. To some degree, therefore, it may be considered an index of general salivary mixture.

A striking feature of the pH determinations made on the soft palate is the fact that the average pH of the 100 cases of the writer,

herein described, almost coincides with the average finding of Brawley in his investigation of the pH of normal resting saliva in 3405 individuals. Brawley found an average of 6.75, and the writer an average of 6.69, with the almost negligible difference of .06.

The foregoing findings in general tend to confirm the standpoint that in the great majority of individuals, the surfaces of all the teeth are seldom subjected to a salivary pH environment representative of a thoroughly mixed saliva in each case. Analytic and pH findings of mixed saliva can not have the most intimate bearing on the etiology of the lesions that are initiated on the crown surfaces.

D. Predilection of Cervical Caries and so-called "Erosion" for the Oral Vestibule

(a) Cervical caries

Dental caries always begins on the surface of the clinical crown and never in the interior of the tooth. The general regions on tooth surfaces where caries is initiated are three in number, viz. in pits and fissures; on proximal surfaces under the contact point; and on labial and buccal surfaces near the gingival line. Labial and buccal cervical caries does not tend, as a rule, to extend beneath the gingival margin, and rarely finds its inception in this region. Clinical observation plainly teaches that the lingual surfaces of the teeth, with the exception of pits and fissures in the upper central and lateral teeth, are seldom attacked. Cervical caries is therefore, in the main, a lesion of the vestibule.

(b) Enamel wasting (so-called erosion)

According to the definition of Miller¹¹ the term wasting "is used in a collective sense to designate any kind of slow and gradual loss of tooth-substance, characterized by a smooth, polished surface without reference to the cause of such loss." The term "erosion" is used to indicate superficial chemical destruction of tooth-substance, and "abrasion" denotes the slow and progressive diminution of the hard tissues of the teeth by friction. When the abrasion is produced by mastication it is commonly known as "attrition".

When the wasting of the tooth-substances is brought about through a combination of chemical and mechanical factors, it is termed "chemico-abrasion". According to Miller, erosion is never identical with wasting. Acids decalcify the enamel, but by themselves fail to produce the smooth, polished surface characteristic of wasting. Miller has also pointed out that "chemico-abrasion differs from abrasion in its greater tendency to attack the enamel of the teeth." The common wastings that begin on the enamel surface therefore are apparently induced by chemico-mechanical factors. These wastings, or so-called erosions, may involve many teeth, or may be confined to one or two upper front teeth. Areas of wasting may range from uniform involvement of the whole enamel surface to peculiar polished cavities of various shapes in the enamel (see Hirschfeld¹²). They rarely affect the lingual surfaces of the teeth, and show a predilection for the labial and buccal surfaces. The upper teeth appear to be involved more frequently than the lowers.

E. The Reaction of the Gingival Crevices

The fluid of the gingival crevice is with few exceptions alkaline in reaction. The writer has made hundreds of approximate pH determinations of the fluid contents of gingival crevices and found, under clinically normal conditions, values ranging from pH 7.3 to 7.5, the normal range of blood. Crevices associated with gingival tissues manifesting congestion and chronic inflammation frequently tend to show a somewhat higher pH.

It will be of interest to point out that cervical caries does not tend to spread under the gingival margin, and seldom, if ever, begins in the gingival crevice. On the other hand, a type of calculus in the form of small scales or granules, and usually darker in color than salivary calculus, is frequently found in this locality. From a clinical standpoint, this concentration often seems to be a resultant, inflammation in general acting as one of the agents.

F. The Importance of Hydrogen-ion Concentration in the Oral Cavity

Seifriz¹³ has stated that "the role of hydrogen in life is so great and so widespread that one can hardly mention a process of an organic nature that is not influenced by these ions."

The part that hydrogen ions play in oral conditions constitutes one of the outstanding problems in dental investigation. For example, it has long been known that acid solutions dissolve enamels in vitro. The effects of freshly secreted saliva on enamel in the oral cavity are unfortunately not so well known, although it is admitted that in exceptional cases when the pH of the saliva is extremely low, solution of the enamel may take place (Forbes¹⁴).

Again, it is known that enzymes are relatively very fragile and among other properties, are sensitive to hydrogen-ion concentration (Holmes,¹⁵ Haldane¹⁶). The saliva contains carbohydrases such as amylase and maltase, and it is obvious that the activity of these enzymes must have some bearing on the retention and hydrolysis of tooth-bearing carbohydrates. It seems apparent that the availability of readily fermentable carbohydrate debris on the tooth surface for bacterial breakdown, and under certain protective conditions, is an important factor in the etiology of dental caries.

Further, it has been demonstrated¹⁷ that the enzyme phosphatase is liberated by degenerated epithelial cells, and that calcium phosphate could be precipitated from saliva through the activity of this enzyme.¹⁸ As desquamated epithelial cells are invariably present in gingival crevices, the alkaline reaction of the contents of these crevices undoubtedly plays a part in the activity of the phosphatase. And it is probable that this mechanism is operative in the formation of subgingival calculus.

G. Conclusions

1. The finding that different reactions are present in different salivas in the same mouth at the same time (e.g. parotid saliva acid in reaction entering the mouth coincidentally with alkaline mandibular saliva) would seem to disprove the contention that the reaction of saliva is a reflection of the reaction of the blood.
2. The concept that a resting saliva exists with a reaction common to the oral cavity as a whole, and that the crowns of all the teeth are ordinarily bathed in such a saliva would seem to rest on false premises.
3. With cervical caries pre-eminently a lesion of the oral vestibule, and with acid salivary reactions predominating in this section of the oral cavity, it seems reasonable to deduce that acid parotid saliva has some etiological relationship with this lesion of the vestibule. This is in contra-distinction to the viewpoint that the pH values of the saliva exert no definite influence on the initiation of the caries process.
4. The mucin content of saliva has been suggested by some writers as a local factor which predisposes to dental caries. It is argued that a saliva rich in mucin is decreased in flushing and cleansing capacity. Being high in viscosity, it flows less freely into the smaller depressions on the tooth surface which harbor bacteria. It must be pointed out, however, that the oral vestibule, notably the division of the oral cavity prone to cervical caries, is under the dominance of parotid saliva, a thin secretion devoid of mucin.
5. It is commonly observed that the lower anterior teeth, in a great many mouths, exhibit a marked immunity to caries, cervical and proximal. It has been shown previously that very frequently the lower anterior region is under the dominance of alkaline submaxillary saliva, not only lingually but also labially. As a rule, the immunity of these teeth to caries has been ascribed to the cleansing action of lips, tongue and food, and the motion of the saliva. Undoubtedly these factors may play a part in cleansing, but the inability of the tongue to play an effective role is only too frequently seen in the production of supragingival calculus. The value of the tongue and lips in cleansing the proximal surfaces of the teeth is extremely small. The gingival crevices are frequently filthy and yet caries does not begin in these zones. It seems reasonable to believe, therefore, that in the case of the lower anterior teeth, the alkaline environment peculiar to this region in many mouths prevents, in some way, the colonization of acidogenic bacteria on the tooth surfaces, as in the gingival crevices.
6. The surface of enamel which has been subject to decalcification, however slight, is naturally more susceptible to wearing under the influence of mechanical causes. While it is admitted that the etiology of wastings is still obscure, it seems reasonable to suppose that the acid secretions in the vestibule, including the abnormal secretions of the labial and buccal mucous glands, play a part in the production of these lesions that favour the labial and buccal surfaces of the teeth. Following a superficial decalcification of

the enamel surface, this layer is removed by brushing with abrasives, or other friction, with the production of the smooth, polished surface characteristic of these lesions. Possibly too, the acid secretions remove certain protective substances laid down on the smooth surface and thus pave the way for decalcification.

7. The viewpoint has frequently been expressed that the exudate from the gingival crevice is acid in reaction in inflammatory conditions. This opinion has not been confirmed by our investigations. On the contrary, the findings tend to show a slight increase in alkaline reaction.

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STUDY NO. 2

PHYSIOLOGY OF THE MASTICATORY APPARATUS

WITH SPECIAL REFERENCE TO THE PROCESS OF WEAR

STUDY NO. 2

PHYSIOLOGY OF THE MASTICATORY APPARATUSWITH SPECIAL REFERENCE TO THE PROCESS OF ~~WEAR~~Outline - A. Nomenclature

B. Normal Involutionary Processes

- C. Wear (a) Wear versus Eruption
(b) Studies on primitive people
 (1) The findings of Stein
 (2) The findings of Cameron
 (3) The findings of Campbell
 (4) The findings of Keith
(c) Müller's studies on wear in modern dentitions
(d) The Theory of Linghorne

D. Conclusions

E. Bibliography

PHYSIOLOGY OF THE MASTICATORY APPARATUS

WITH SPECIAL REFERENCE TO THE PROCESS OF WEAR

A. Nomenclature

In 1920, the writer first used the term "periodontium" to designate the supporting tissues of the teeth, and to embrace as the three essential tissue-components, the gingivae, the periodontal membrane and alveolar process. As the word "periodontium" was occasionally used to denote the periodontal membrane, it was felt that the usage of the term in this new sense would make for exactness in terminology.

In 1932, the writer¹ created the term "dento-periodontal unit" which obviously was intended to indicate the tooth and its supporting structures. Our conception of function, as related to the periodontal tissues postulates a mechanism which embraces two "dento-periodontal units", and involves their relationship to each other when the jaws are closed under biting pressure.

From the standpoint of structure of the tooth itself, there is the division of anatomic crown and root. The "anatomic crown" of course is the part of the tooth which is covered with enamel. The part covered with cementum is the "anatomic root". Since the introduction of Gottlieb's theory² of continuous eruption, the terms "clinical crown" and "clinical root" are in common usage. The clinical crown is the part of the tooth that projects from the base of the gingival crevice. The remainder of the tooth is the "clinical root".

B. Normal Involutionary Processes

Gottlieb has specified the following processes as comprising the normal involution of the teeth.

1. The migration of the epithelial attachment toward the apex
2. The simultaneous atrophy of the alveolar crest
3. The protrusion of the teeth toward the occlusal line
4. The mesial displacement of the teeth
5. The compensating abrasion of the teeth both at the occlusal surface and at points of contact

These processes are described as being continuous although at varying pace.

C. Wear

(a) Wear versus eruption

The clinical crown is about two thirds the length of the "anatomic crown" when the tooth has erupted to the occlusal line. Under ideal conditions, during further extrusion of the tooth, the height of the clinical crown remains constant. This is made possible by a compensating

wear or attrition of the incisal or occlusal surface of the tooth. In other words, when the rate of wear balances the rate of eruption, the clinical crown remains constant in height. When the teeth do not wear down at a rate proportional to the eruption, the length of the clinical crown is thereby increased. This implies an increase in length of the extra-alveolar lever arm, and other things being equal, the greater is the stress produced in the periodontal membrane under biting, and masticating pressure. When one tooth erupts faster than its neighbours, and is not worn down proportionately, traumatogenic occlusion is frequently established.

Gottlieb has also pointed out that constant wearing down of the masticating surfaces during eruption is essential in order to avoid "opening of the bite" in the anterior region. Wearing of the tooth surfaces, then, would seem to be the ideal regulator of the articulation as this method of adjustment is operative throughout the animal kingdom.

(b) Studies on primitive people

(1) The findings of Stein³

This investigator in his studies of the effect of attrition upon occlusion has made a most valuable contribution to the subject. He has pointed out that "sturdy well worn dentitions are as rare among civilized races as they are common among the uncivilized." In his study of the normal process of attritional abrasion, Stein selected a group of early American Indians for material. He believes that the best subjects for this investigation are found in primitive inbred isolated communities. Here a decreased variability of tooth and arch form is manifested, and individuals showing dominant family characteristics are to be found belonging to every physiological age.

Stein has stated: "The life history of the occlusal surface of an upper or lower first molar graphically delineates the ontogeny of the masticatory apparatus. This surface is constantly changing in outline and pattern. There appears from time to time, in the life cycle of the molar, typical phases of surface anatomy which are familiar to the dentist. Very often these phases have been erroneously regarded as representative types of occlusal surfaces. In reality they are only transitory phases of the life cycle."

Stein has depicted the seven ages of molar occlusion as follows:

- Stage 1 - The first molars have erupted but have not made contact.
- Stage 2 - The period in which the first molars make contact; the teeth are unworn and the surfaces of the cusps are convex.
- Stage 3 - The occlusal contact points are worn down to small polished surfaces.
- Stage 4 - The small round surfaces of contact become larger until they meet at a line angle along the cusp ridge. They are worn down to quadrilateral planes.
- Stage 5 - The enamel is worn through at tips of lingual cusps, exposing the dentine. The dentine wears away faster than the surrounding enamel.

Stage 6 - The concave areas have greatly increased in size. Secondary dentine begins to fill in the horns of the pulp chamber.

Stage 7 - No enamel is left on the occlusal surface; the grinding area is now almost a flat plane; secondary dentine has obliterated the pulp chamber.

In stage 4, according to Stein, abrasion has begun to decrease the vertical intermaxillary height. The crests of the cusps have been worn away and the cusp angles are decreased in steepness. In stage 5, the cusp angulation is almost lost and the lingual cusps on the upper molars have been eliminated. In the lower molars, the buccal cusps are worn away. The buccal cusps tend to remain in the upper molars, as do the lingual cusps of the lower and a characteristic angle of wear is created. The occlusal surface of the upper molar slants upward and faces lingually; the occlusal surface of the lower molar is the reverse.

Stein points out the interesting phenomenon that the cusps which are worn more rapidly, viz. the lingual cusps in the uppers, and the buccal cusps of the lower molars, are abraded on two sides. The buccal cusps of the upper molars and the lingual cusps of the lower molars are worn on one side only. This combination is a factor that contributes to the characteristic angle of wear..

(2) The findings of Cameron⁴

In his splendid studies of the skeleton of prehistoric man this investigator had made many references to the teeth. It is interesting to note that he found "the dentition of British Neolithic Man essentially modern in every respect."

All the incisor and cuspid teeth from Neolithic to Anglo-Saxon times, examined by Cameron showed by the type of wear that these teeth had met in an end-to-end occlusion. He points out the difference between this relationship and "the modern overlapping bite".

The first molar teeth, both upper and lower, in all the dentitions from Neolithic to Anglo-Saxon times showed a type of wear typically associated with an end-to-end occlusion in the incisor region. This wear was usually found to be present on the second bicuspid teeth as well. These teeth showed that attrition took place early and in a characteristic fashion. The upper first molars showed marked wear of the lingual cusps which in some cases were completely lost by middle life, and lingually the teeth were worn to the gum line. The buccal cusps show much less wear, and in consequence there is produced a slanting occlusal surface which slopes upwards and faces lingually. The wear of the lower antagonists is of course in the opposite direction. It is to be noted that this characteristic angle of wear finds its counterpart in the first molar teeth of the American Indians described by Stein. Cameron found the second molar teeth only occasionally involved in this angulation of wear, the third molars never. Cameron found that this type of wear was also manifested by teeth from a Copper Age burial in Minorca, and the Anglo-Saxon population from Guildown. His findings on Eskimo crania of the Canadian Arctic Expedition, 1913, showed that the wear on the molar and incisor teeth conformed in every way to that displayed by British Neolithic man.

Cameron did not find, in all the prehistoric skulls examined, a single case showing alveoli that had undergone absorption. This showed that the dentitions had been preserved intact.

These findings indicate that in prehistoric man early wear of the teeth was the rule. Interfering cusps were quickly worn off and no individual loading was permitted with its common sequela of lost teeth. Obliterated cusps, flattened surfaces, and intact dentitions form the ordinary clinical picture. Cameron came to the conclusion that for the transition from the end-to-end bite in the incisor region to overlapping, modern methods of cooking are partly responsible.

(3) The findings of Campbell⁵

This observer in his noteworthy study on the dentition and palate of the Australian Aboriginal, points out that the edge-to-edge bite is well known to be typical of the Australian dentition. In discussing this condition, he has stated: "In any series of Australian skulls which included sufficient specimens of varying ages, it can be seen that the presence of the edge-to-edge is associated with the occlusal wear the teeth have undergone; that is, a diminution in the cusp height of molars and premolars is accompanied by an apparent shifting forward of the lower anterior teeth relative to the upper anterior."

From a study of the occlusion in Australian specimens of various ages, beginning with young specimens with the upper incisors overlapping the lower, and passing through older subjects until adult specimens show typical edge-to-edge bite, Campbell has concluded that this condition "though present in the adult almost without exception, was a modification only acquired by the attaining of adult age."

It was observed that the position of the lower first molar in relation to the upper first molar, in the final adult stage of edge-to-edge bite in the incisor region, is practically unchanged from the earlier stages. In consequence, according to Campbell, the main change must be considered as having taken place in the anterior region of the arches.

(4) The findings of Keith⁶

Sir Arthur Keith, in a survey of palates and jaws of British people-- fifty ancient (buried in England before the date of the Norman conquest) and fifty modern skulls (chiefly Londoners of the eighteenth and nineteenth centuries)--made a most interesting observation. Forty-seven of the dentures of the ancient British skulls presented an end-to-end occlusion in the incisor region while all the modern skulls showed definite overlapping in the same region. This gradual transition from an end-to-end occlusion to one of overlapping implies a change from a relatively vertical loading to horizontal loading in the anterior region.

It is suggested by the writer that the explanation, in part at least, of this failure of the modern dentitions to arrive at the final normal adult stage as represented in primitive dentitions, viz end-to-end occlusion, may be found in the decreased attrition of the teeth. This in turn is the result of a decrease in the abrasive action of the food through reduction in the coarseness of the foodstuffs and the amount of contained grit.

The reference to the Norman Conquest would appear to be significant in this regard. In Celtic Britain, the corn was ground in stone handmills called querns. No traces of Roman watermills have been found in England. If such existed they were probably destroyed on the departure of the Roman legions. In Anglo-Saxon times, a large number of mills were built. The Domesday Book, which is the record of the great survey of England in 1086, executed for William the Conqueror, mentions a great number. Undoubtedly an enormous number of handmills were in operation in Anglo-Saxon times and even following the Conquest for some time. However, with the coming of Norman feudalism the villeins were compelled to take their corn to the lord of the manor for grinding.⁷ Many ground their own corn by stealth for a time. Nevertheless, one of the results of the Norman Conquest was the great increase in windmills and watermills under the control of the lords and the gradual elimination of the handmill.

Undoubtedly, the sarsen-stone, or sandstone, as used in some of the earlier querns was responsible for some of the early and excessive wear of the teeth, in different localities. This has been suggested to Cameron by Mr. Keiller in charge of excavations at Windmill Hill, England. It seems reasonable that the change from handmills would be attended by a decrease in the amount of grinding grit and consequent decrease in attrition of the teeth. It can hardly be denied that the whole trend down to modern times has been toward refinement of the flour. And with the introduction of methods for the removal of extraneous matter such as dust and earth from the wheat, and the use of roller mills instead of millstones, it must be admitted that the abrasive action of the modern clean fine product is almost negligible.

(c) Müller's studies on wear in modern dentitions⁸

Müller found in a study of his collection of models of jaws with the full number of teeth present that all stages of worn facets were shown. The third molars were found to exhibit a peculiar type of wear which differs from the other molar teeth. These, viz. the first and second molars, in the upper jaw, are worn down in such a way that the inner side is lost, while in the lower jaw the reverse is true, the loss being shown on the outside. We see in these teeth the counterpart in the modern dentition of the findings of Stein and Cameron in prehistoric peoples.

It was found that in the case of less worn teeth, the facets are, in general, parallel to each other with only a slight increase in steepness as the front teeth are approached. But when the wear becomes more pronounced, it was found the directions of the facets differ, falling off more steeply towards the outside in the case of the lowers and increasing towards the front.

(d) Linghorne's Theory of nature's plan for the dentition⁹

Recently a new theory involving the physiology of the masticatory machine has been presented to the dental profession by Doctor W. J. Linghorne of New Liskeard, Ontario. This theory was evolved following certain observations that the majority of elderly people who retained their teeth without the development of periodontal disease exhibited

teeth with the cusps well worn down and presenting fairly flat surfaces. Further, this theory was developed with the knowledge that continuous eruption of the teeth and secondary dentine formation were normal processes in the involution of the denture. This theory in Dr. Linghorne's own words, is as follows:

"When the permanent teeth erupt, the function of the cusps is first, to engage the planes of the cusps of the opposing teeth in order to guide them into the correct position with the help of the muscles of the lips, tongue and cheeks; second, to help maintain them in that position until there is a sufficient strengthening and hardening of the supporting bone to maintain the teeth in their correct relation without the aid of the interlocking cusps. The second purpose of the cusps of maintaining the teeth in the correct position is being taken care of, gradually and progressively, by the change in the supporting bone; until, in early adult life, the cusps in their original form have lost their reason for existing. During this period the cusps should be worn down gradually by the chewing of coarse abrasive foods until finally in the adult the time arrives when the supporting bone completely takes over the second function of the cusps, and the latter disappear.

Then in an occlusion of this type, there is no premature engaging of certain teeth, because any high spots in the occlusion have been worn off. Also the force of mastication is exerted on the teeth in a direction at right angles to the surface of the teeth, which being substantially flat is in the direction of the long axes of the teeth.

A force directed on the long axis of a tooth will be transmitted through the periodontal membrane and due to the cone shape of the root will be distributed equally over the supporting bone structure.

A mouth showing normal overbite at completion of eruption would in the adult show no overbite with an end-to-end occlusion."

This theory may be summarised as follows:

1. Function of the cusps

- (1) Guidance of the teeth into their correct positions
- (2) Maintenance of the teeth in these positions until the bone is strong enough to assume this function without cusp aid

2. Function of wear

- (1) Removal of the cusps gradually, the bone taking over the maintenance function of the cusps
- (2) Through gradual diminishing of incline plane control of the cusps through wear, the teeth move to an end-to-end occlusion under the operation of pressure of lips, cheeks and tongue.

These processes are gradual and blend harmoniously one into the other. The strengthening of the bone is gradual and progressive until wear is permitted, which in turn allows the gradual operation of the forces of the lips, cheeks and tongue to establish an end-to-end occlusion.

This tends to decrease horizontal loading, and induces heavy function within the normal tissue limits resulting in the development of strong periodontal structures. According to this theory, the component of wear assumes a place of first importance in the physiology of the masticatory apparatus. Due to the lack of abrasive quality in our modern diet, the wear frequently does not compensate for the eruption of the teeth. Deficient wear results in the persistence of interfering cusps that tend to produce individual overloading of the teeth. It also prevents the trend toward the development of a normal axial loading with its attendant benefits. Wear, under normal conditions through elimination of incline planes is constantly tending to change from horizontal loading to axial.

According to the Linghorne theory, the use of an artificial adjunct of an abrasive nature is recommended where indicated. The object is to keep the component of wear in harmony with the other factors operating in the normal physiology of the denture. It is aimed to produce an attrition that is proportional to the rate of eruption, and the maintenance of an articulation that harmonizes with the ideal normal for any given period in the life cycle of the masticating machine.

D. Conclusions

1. The problem of wear in its various aspects is one of great importance. It would seem that its place in the normal physiology of the denture has not been fully appreciated by the dental profession.
2. Sturdy well-worn dentitions point to the benefits that accrue from heavy function of a particular kind, viz. one that tends to distribute the stress fairly evenly over the periodontal membrane and bone.
3. Modern dentitions, generally speaking, show a retarded degree of occlusal wear in early adult life. In consequence, the ideal adult stage viz. end-to-end occlusion in the anterior teeth, is seldom achieved. As sequelae, well developed supporting structures are relatively uncommon, and interfering cusps are permitted to remain with attendant individual overloading.
4. In view of the lack of abrasive action of our modern diet, the use of an adjunct to supply this need is plainly indicated. Its use obviously should be under the observation and control of the dental practitioner.
5. Teeth with poorly developed periodontal structures stand in special need of such an adjunct.
6. The opinion occasionally expressed that premature wear results in disuse atrophy does not seem to rest on sound clinical examination.
7. The view that cusp height and steepness of incline planes are necessary to periodontal health in youth would seem to be open to question.
8. Valuable information in methods of occlusal correction is to be gained from a close study of normal abrasion in sound healthy dentitions of primitive peoples.

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STUDY NO. 3

THE INFLUENCE OF HEAVY FUNCTION AND LACK OF FUNCTION ON THE
PERIODONTAL MEMBRANE AND SUPPORTING BONE

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Outline - A. The Functions of the Periodontal Membrane

- (a) The physical function particularized

B. The structure of the Periodontal Membrane

- (a) Black's classification of fiber bundle groups

C. Divisions in regard to Function: 1. Heavy Function

2. Lack of Function

- (a) Tissue findings in heavy function - periodontal membrane and supporting bone

- (b) Principles of Adami

- (c) Alveolar and Supporting Bone

D. Lack of Function

- (a) Influence on periodontal membrane

- (b) Influence on supporting bone

E. Bibliography

THE INFLUENCE OF HEAVY FUNCTION AND LACK OF FUNCTION ON THE
PERIODONTAL MEMBRANE AND SUPPORTING BONE

A. The Functions of the Periodontal Membrane

In 1933, the writer stated¹ that "the rapid march of scientific dentistry will depend in large part on the development of periodontal physiology and its application by discerning pathologists and practitioners to their respective fields." It seems obvious that the work of the periodontist and orthodontist, for example, must be inseparably associated with advances made in this subject.

Based on sound observation, in general it may be said that the functions of the periodontal membrane are as follows:

- (a) physical
- (b) sensory
- (c) nutrient
- (d) formative

(a) The physical function may be particularized as follows:

(1) It acts as an apparatus for diminishing the force of concussion with an opposing body whether it be dental or otherwise. (Hopewell-Smith)²

(2) It affords a fibrous attachment to the teeth, Malassez in 1885 comparing it to a ligament. (Hopewell-Smith)

((3) It provides a layer of soft material in which blood vessels and nerve fasciculi to supply the teeth may ramify without risk of damage or permanent and inoperable injury by mechanical shock. (Hopewell-Smith)

(4) It sustains the soft tissues in their proper relation to the teeth. (Noyes)³

(5) Through its principal fibers it transmits, under loading, functional stimuli to the alveolar bone. (Orban)⁴

B. The Structure of the Periodontal Membrane

It is common knowledge that the periodontal membrane consists largely of fibrous connective tissue, the fibers of which are of the white variety. They may be divided into two classes, viz:

- (a) the principal fibers of Black
- (b) the indefinite fibers

(a) The principal fibers are embedded in the cementum on one side and in the bone on the other, with the exception of the marginal gingiva, and are arranged in fairly well defined groups.

According to Black's well-known classification, these are as follows:

(1) the free gingivae group - extending from the cementum into the gingival crest, and encircling the tooth. They are more marked on the lingual than on the labial.

(2) the transeptal group - extending from the cementum on the proximal surface of one tooth across the septal gingivae to the proximal surface of the neighbouring tooth. This group binds two adjacent teeth and assists in holding the contact points of the teeth together.

(3) the alveolar crest group - extending from the cementum to the crest of the alveolar process. This group is frequently called the dental ligament, and helps to support the tooth against lateral pressure. The fibers withstand heavy stresses of compression and traction.

As Coolidge⁵ had pointed out, these three groups of fibers are superficially located and constitute a large part of the body of the septal, labial, and lingual gingivae, and the next three groups make up the periodontal membrane proper, and furnish the greater part of the support of the tooth. These are as follows:

(4) the horizontal group - extending from the cementum to the alveolar bone near the crest. It furnishes a strong band of attachment and operates against lateral pressure.

(5) the oblique group - extending from the cementum in an oblique direction occlusally to the alveolar bone. It largely constitutes the body of the periodontal membrane; suspends the tooth in its alveolus, and supports it against axial pressure.

(6) the apical group - radiating in fan-like bundles between the cementum and the alveolar bone. In general it acts as a cushion and helps to support the apex against lateral forces delivered against the crown.

Regarding the disposition of the principal fibers, Noyes has stated: "It is necessary, however, to remind the student that connective tissues are formed in response to mechanical conditions and stimuli, and therefore this arrangement must be considered, not as having been designed to sustain the forces, but as being the result of the forces to be sustained and therefore beautifully adapted to them."

(b) The indefinite fibers and cells fill in the spaces between the fiber bundles, and follow the course of the blood-vessels and nerves, forming in large part the supporting tissue of these structures.

C. Divisions in Regard to Function

It will be of great importance to understand some of the changes that occur in the periodontal membrane and bone following modifications of the physical or occlusal function of the tooth. Based on available clinical diagnosis, some of the changes found associated with the following two broad divisions, in regard to function involving the relationship of two dento-periodontal units under biting pressure, will be described. These divisions are as follows:

1. Heavy Function
2. Lack of Function

1. Heavy Function

(a) Tissue findings in heavy function

Heavy Function, viz, increased stress within the limits of the reserve force of the cell. The histologic picture shows hypertrophy or fine development of the fiber bundles with decrease in the amount of indifferent tissue. There is also good development of the supporting bone.

(b) Principles of Adami

As an aid to a better understanding of these changes, the following statements of Adami and McCrae⁶ are apropos.

1. "If cells are put upon a constant not excessive stretch or even are exposed intermittently to such a stress, if they be well nourished, proliferation ensues, the distension acting as a stimulant."
2. "Mechanical force exerted either as pressure or traction upon a cell is able to cause the growth and proliferation of that cell so long as at the same time there is no interference with its nutrition, and the force acting on the cell is not excessive."

As the changes in the periodontal membrane, brought about by heavy function, are adaptive changes and due to alterations in environment, the following statements of Adami⁷ are of interest.

1. "Cellular structure is the expression of the chemical constitution of the cells."
2. "Histological alteration presupposes modification in the arrangement and intimate constitution of the molecules of living matter."
3. "All living matter exhibits obvious adaptation to the conditions under which it manifests its activity."
4. "Modifications in properties demand modification in the constitution of the cell substance; at base, therefore, adaptation indicates molecular alteration and rearrangement in the living matter of the cell."

(c) Alveolar and supporting bone

It is perhaps in order here to call attention to the distinction made by Orban⁸ between "alveolar bone" and "supporting bone". According to this investigator, "only the inner layer of bone surrounding the root may be considered alveolar bone; the other bone adjacent to the alveolar bone is the bone of the jaw and supports the thin alveolar bone." He points out, also, that "on the labial and lingual surfaces, in some locations, the bone surrounding the teeth is very thin and consists largely of alveolar bone." This distinction between alveolar bone and supporting bone is of considerable importance as they differ in function. The alveolar bone depends largely on the presence of the tooth, while the supporting bone is influenced greatly by the function of the tooth. Kronfeld⁹ has stated: "The greater the functional stress, the stronger and denser will be the supporting bone. In case of lack of function, the supporting bone will be almost entirely missing; only the thin outer and inner alveolar plates will be left."

Increased stress inducing physiological hypertrophy of periodontal fiber groups and strong supporting bone is commonly found on well-worn teeth in which the loading is mainly axial.

The viewpoint that the greater the functional or occlusal force becomes, the stronger will be the supporting bone, would seem to need some qualification. When the cusps have been worn down enough to produce mostly an axial loading, the bone receives the stress more evenly over the entire alveolus. In consequence, heavy function tends to be beneficial, and may be increased considerably without the danger of overloading. However, in the writer's opinion, great increase in functional stress, that acts on the tooth more or less horizontally and is sustained by the periodontal membrane and bone regionally instead of generally, is frequently outside the normal limits of the tissues and is not beneficial. On the contrary, changes take place that represent an expression of a reaction on the part of the tissues to injurious agencies.

D. Lack of Function

(a) Influence on periodontal membrane

A number of investigators have shown that the periodontal width in the case of functionless teeth is narrower than those in function. (See the works of Kellner, Klein and Kronfeld.¹⁰) In some cases, this width has been found to be about one-third the normal functional measurement. This has a profound bearing on the tightness of the tooth in its socket.

The periodontal membrane of functionless teeth of relatively long standing consists largely of a very loose tissue. This is in decided contrast to the membrane of teeth in heavy function where the fiber bundles are well developed and the zones of supporting indifferent tissue are small. Compared to this ideal normal, in the membrane of functionless teeth, the tissues lose their cellularity and striking architecture of cells and processes, with decrease in the number of fibers and density of fibrillar arrangement. To this condition of atrophic changes, the writer¹¹ has given the term "adaptive fibropenia".

(b) The supporting bone, in the case of lack of function, shows a resorption of the trabeculae and a replacement by fatty marrow.

In mild function there is a decrease in the development of fiber bundles as compared to heavy function, with an increase in the size of the tracts of indifferent fibrous tissue. The findings in the microscopic pictures of periodontal membranes where fiber bundles and zones of loose tissue are found in different ratios, therefore may be looked upon as authentic records of the adaptation of the membrane to varied and fine modifications of physical function.

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